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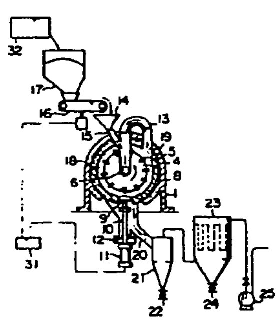
(54) **Method of improving quality of surface of solid particles and apparatus thereof.**

(57) A method of and an apparatus for improving quality of surface of mother particles are disclosed, in which fine particles (hereinafter referred to as child particles) or liquid containing or not containing child particles (that is, solution such as water or solution of various materials. When liquid is cooled and fixed on surface of mother particles, the liquid is named a film forming material) is previously adhered or is not adhered to surface of solid particles (hereinafter referred to as mother particles) forming powder and cores, and an impact striking devide is employed to embed, fix, melt or beat out child particles to surface of mother particles or to form film of liquid.

FIG.2



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METHOD OF IMPROVING QUALITY OF SURFACE OF SOLID PARTICLES AND APPARATUS THEREOF

FIELD OF THE INVENTION AND DESCRIPTION OF RELATED ART

The present invention relates to a method of and an apparatus for improving quality of surface of solid particles forming powder by fixing other material, for example, other solid particles or liquid on surface of the solid particles forming cores by means of an impact striking measure.

More particularly, the present invention relates to a method of and an apparatus for improving quality of surface of particles (hereinafter referred to as mother particles) by adhering fine particles (hereinafter referred to as child particles) on surface of the mother particles forming cores previously or by embedding or fixing the child particles on surface of the mother paricles by an impact striking measure instead of adhering the child paricles.

The present invention also relates to a method of and an apparatus for improving quality of surface of mother particles by adhering child particles on surface of the mother particles forming cores previously or by fixing the child particles on surface of the mother particles by means of an impact striking measure and further softening and melting the whole or part of the child particles instead of adhering the child particles.

Further, the present invention relates to a method of and an apparatus for fixing child particles formed of metal on surface of mother particles by adhering the child particles of metal on surface of the mother particles forming cores previously or by fixing the child particles of metal on surface of the mother particles by means of an impact striking measure and further beating out the whole or part of the child particles of metal by an impact striking measure instead of adhering the child paticles.

The present invention relates to a method of and an apparatus for improving quality of surface of mother particles by attaching a solution such as water containing child particles or a solution of various materials (the solutions being generalized as a liquid and when liquid is cooled and fixed on surface of mother particles, the liquid is named a film forming material) on surface of the mother particles forming cores and drying or cooling the liquid to fix the child particles on the surfaces of the mother particles or to form a film of the solution on surface of the mother particles.

The present invention relates to a method of and an apparatus for improving quality of surface of mother particles in which other child particles are attached or implanted to surface or cavities of the mother particles having surface formed in various uneven shapes or with holes or grooves and an impact striking measure is employed to soften, melt and transform projections of the mother particles to embed the child particles into the mother particles.

Heretofore, improvement of quality of surface of solid particles such as prevention of lumping of solid particles, prevention of change of color and quality, improvement of dispersion, improvement of catalytic effect, improvement of control of digestion and absorption, improvement of magnetic characteristic, improvement of color tone, improvement of light-resisting characteristic, improvement of reduction of effective or expensive material, and the like have been made by electrochemical method, physical absorption method, chemical absorption method, vacuum deposition, electrostatic adhesion method, method of covering with melted material, special spray-drying method, flowing coating method, rolling coating method, and the like. Particularly, in case of improving quality of surface of solid particles by using solid particles, that is, in case of improving quality of surface of powder by using powder, and in case of improving quality of surface of solid particles by using suspension of fine particles of various material or solution of various material, as well-known agitator of various mixer types or ball mill type is employed to make agitation thereof for a long time, for example, several hours to several tens hours. Electrostatic phenomenon, slow drying phenomenon and mechanochemical phenomenon caused by the agitation are applied to improve quality of surface of solid particles. However, since close adhesion of child particles or film material to mother particles is not sufficient and force applied to mother particles is not even, the film is formed sparsely. Consequently, when powder which has been subjected to improvement process is subjected to work in a next process such as mixing, mixing and kneading, dispersing, pasting or the like, child particles are removed easily and segregation of components is caused, so that operation condition is not only limited extremely but also quality of a worked product is varied widely.

Further, in improvement of quality of surface of solid particles in powder-powder system, powder-suspension and powder-solution system by using the various type mixer and ball mixer, since fixing force of child particles or film forming material to surface of mother particles is generally weak. Accordingly, in order to obtain desired quality of surfaces of solid particles, it is required to take several hours to several tens hours, the apparatus therefor is large in size and working efficiency is extremely low.

In addition, while various micro capsule methods have been employed in the case where removal characteristic of material is controlled, all methods are of wet type. However, a subsequent process requires a drying process and application fields of thechnique are limited with poor generality.

A method of improving quality of surface of solid particles in powder-suspension system and powder-solution system contains a jet mill method utilizing fluid energy, in which mother particles impinge to each other by fluid energy at potential core portion of jet stream. However, since operation of separating child particles from mother particles is rather stronger than operation of fixing child particles to mother particles on the average, effective fixation of child particles to mother particles if very difficult. There is an example of coating solution to mother particles, in which since heat-isolated expansion of pressurized air is utilized as fluid energy, cost of power per production is increased and quality of products after improved is varied widely. Further, when a diameter of solid particles of which quality of surface is to be improved is relatively large (500 um or more), fluid coating method or rolling coating method is used. However, when the diameter of particles is 100 um or less, particles consense to be lumped due to viscosity of solution used for improving quality and it is impossible to improve quality of surfaces of individual fine particles.

OBJECT AND SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to a method of and an apparatus for improving quality of surface of solid particles in which the above problems in the prior art are removed.

It is another object of the present invention to provide a method of improving quality of surface of solid particles in which it is characterized to fix other material to the surface of the solid particles by using impact striking measure.

More particularly, as shown in Fig. 1, the present invention provides a method in which child particles are forcedly and firmly implanted or fixed on the whole surface of a mother particle by using mechanical means and if necessary using thermal means as auxiliary means so that quality of the surface of the particle forming powder is improved to be uniform and stable in a very short time (several seconds to several minutes) and thereby functional composite material (hybrid powder) can be obtained, and the gist of the present invention resides in the surface quality improvement method of solid particles characterized by fixing child particles to surface of mother particle by implantation or fixation of child particles by using impact striking means (first embodiment).

Further, as shown in Fig. 6, the present invention provides a method in which child particles are forcedly implanted or fixed on the whole surface of a mother particle by mechanical means and if necessary using thermal means as auxiliary means and the whole or part of the child particles are melted to be fixed on the surface of the mother particle so that quality of the surface of the particle forming powder is improved to be uniform and stable in a very short time (several seconds to several minutes) and thereby functional composite material (hybrid powder) can be obtained, and the gist of the present invention resides in the surface quality improvement method of solid particles characterized by implanting or fixing child particles on the surface of mother particle by using impact striking measure and further softening and melting the whole or part of the child particles so that the child particles are fixed on the surface of the mother particles (second embodiment).

Further, as shown in Fig. 6, the present invention provides a method in which metal child particles are provided on part or the whole of surface of mother particle and the whole or part of the metal child particles are forcedly beatenout to be fixed on the surface of the mother particle by using mechanical means and if necessary using thermal means as auxiliary means so that quality of the surface of the particle forming powder is improved to be uniform and stable in a very short time (several seconds to several minutes) and thereby functional composite material (hybrid powder) can be obtained, and the gist of the present invention resides in the surface quality improvement method of solid particles characterized by beating out metal child particles on surface of mother particle by using impact striking measure so that the metal child particles are fixed on the surface of the mother particle (third embodiment).

As shown in Fig. 8, the present invention provides a method in which child particles or film forming material is forcedly implanted or fixed or films on part or the whole of surface of mother particle by using mechanical means and if necessary using thermal means as auxiliary means so that quality of the surface of the particle forming powder is improved to be uniform and stable in a very short time (several seconds to several minutes) and thereby functional composite material (hybrid powder) can be obtained, and the gist of the present invention resides in the surface quality improvement method of solid particles characterized by drying or cooling liquid on the surface of solid particle to fix other fine solid particles contained in the liquid or film of material forming liquid on the surface of the solid particle (fourth embodiment).

Further, as shown in Fig. 12, the present invention provides a method in which mother particle is covered with child particles by means of dry-type mechanical means and part of the mother particle is softened or melted or transformed to embed the child particles into the mother particle so that quality of the surface of particle forming powder is improved to be uniform and stable in a very short time (several seconds to several minutes) and thereby functional composite material (hybrid powder) can be obtained, and the gist of the present invention resides in the surface quality improvement method of solid particle characterized by embedding other solid particles in cavities of the solid particle having surface formed in various uneven shapes or with holes and grooves and softening or melting or transforming the solid particle by using impact strking means so that the other solid particles are fixed in the solid particle by embedding the other solid particles into the solid particle (fifth embodiment).

In addition, the present invention is to provide an apparatus for implementing the above methods, and the gist thereof resides in a surface quality improvement apparatus of solid particle comprising an impact chamber including impact striking means, a supply inlet for feeding solid particles into the impact chamber and an circulating path which communicates from an outlet of the impact chamber to the supply inlet.

The present invention is to provide a surface quality improvement apparatus of solid particles further comprising, in addition to the above apparatus, a nozzle for feeding liquid into at least one of the impact chamber, the supply inlet and the circulating path, heating means and supply means for supplying inert gas.

BRIEF DESCRIPTION OF DRAWINGS

Figs. 1(1) to (8) schematically illustrate various states of powder particles before and after improvement of surface quality thereof by the method and apparatus according to the present invention;

Fig. 2 schematically illustrates a powder impact apparatus according to an embodiment of the present invention together with peripheral apparatuses;

Fig. 3 is a side view of the apparatus of Fig. 2;

Fig. 4 schematically illustrates a powder impact apparatus according to another embodiment of the present invention in the case where inert gas is used;

Fig. 5 shows photographs of powder particle, of which quality of surface has been improved, taken by a scanning electron microscope and in which Fig. 5(1) shows the power particle 6000 times, (2) 20000 times and (3) 40000 times;

Figs. 6(1) to (8) schematically illustrate various states of powder particles before and after improvement of surface quality thereof according to another embodiment of the present invention;

Fig. 7 shows photographs of powder particle, of which quality of surface has been improved, taken by a scanning electron microscope and in which Fig. 7(1) shows electrostatic adhesion 10000 times, (2) 8500 times for implementation No. T-11, (3) 10000 times for implementation No. T-12 and (4) 10000 times for implementation No. T-13.

Figs. 8(1) to (11) schematically illustrate various states of powder particle before and after improvement of surface quality thereof according to still another embodiment of the present invention;

Fig. 9 schematically illustrates an embodiment of a powder impact apparatus used in the embodiment of Fig. 8 together with peripheral apparatuses;

Fig. 10 is a side view of the apparatus of Fig. 9;

Fig. 11 schematically illustrates a powder impact apparatus according to another embodiment of the present invention in the case where inert gas is used;

Figs. 12(1) to (4) schematically illustrate various states of powder particle before and after improvement of surface quality thereof according to a still further embodiment of the present invention;

Fig. 13 shows photographs of powder sample used in the embodiment of Fig. 12 and taken by a scanning electron microscope, and in which Fig. 13(1) shows porous nylon material (2000 times), (2) mother particle with child particles adhered thereto (5000 times) and (3) mother particle of which surface has been improved by impact striking means and in which child particles are embedded therein (5000 times); and

Fig. 14 shows photographs of powder particle taken by a scanning electron microscope before and after processed to sphere according to a still further embodiment of the present invention, and in which Figs. 14(1) and (2) show powder particle 1000 times.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

A first embodiment of the present invention is now described.

Representative mother particles of which surface can be processed by the method and the apparatus of the present invention have generally a diameter of about 0.1 μm to 100 μm and are formed of pigment such as titanium dioxide and iron oxide, synthetic high molecule material such as epoxy powder, nylon powder, polyethylene powder and polystyrene powder, and natural material such as starch, cellulose and silk powder. Representative child particles have generally a diameter of about 0.01 μm to 10 μm and are formed of natural material, synthetic material and various synthetic pigment such as silica colloid particles, alumina colloid particles, titanium dioxide powder, hydrozincite powder, iron oxide powder, mica powder, calcium carbonate powder and barium sulfate. However, both particles are not limited to the above materials and are applicable to combined components of various materials used in industries such as chemical industry, electrical industry, magnetic industry and various other industries dealing with cosmetics, paints, printing ink, toner, color material, fiber, medicine, foods, rubber, plastic, ceramic and the like.

There are generally used mother particles having large diameter and small hardness and child particles having small diameter and large hardness. However, relation of the diameter and hardness between mother particles and child particles is reversed depending on combination of largeness of particles. That is, softer child particles can be fixed to surface of harder mother particles.

An embodiment of the present invention is now described in detail with reference to drawings.

Figs. 2 and 3 show an example of impact striking means using an impactor. In the figures, numeral 1 denotes a casing of a powder impactor (a representative impactor) used for implementing the method of the present invention, numeral 2 a back cover thereof, numeral 3 a front cover thereof, numeral 4 a rotating plate provided in the casing 1 and which rotates at a high speed, numeral 5 a plurality of impact pins disposed on the outer periphery of the rotating plate 4 radially at regular intervals and which are generally of hammer type or plate type, numeral 6 a rotary shaft for supporting the rotating plate 4 in the casing 1 rotatably, numeral 8 a collision ring disposed along an outermost peripheral orbital face of the impact pins 5 and facing the impact pins 5 while maintaining a constant space between the impact pins 5 and the ring 8 which uses an uneven type of various shapes or a circumferential flat plate type, numeral 9 an opening and closing valve provided in a notch formed at a portion of the collision ring 8 for exhausting powder for used to improve quality, numeral 10 a shaft for the valve 9, numeral 11 an actuator for operating the valve 9 through the shaft 10, numeral 13 a circulating circuit having one opening formed at one end and coupled with a portion of the inner wall of the collision ring 8 and the other opening formed at the other end and coupled with a center of the rotating plate 4 to form a close circuit, numeral 14 a hopper for raw material, numeral 15 a shoot coupling between the hopper 14 and the circulating circuit 13 for supplying raw material, 16 a metering feeder for raw material, numeral 17 a reservoir for raw material, numeral 18 a collision chamber provided between the outer periphery of the rotating plate 4 and the collision ring 8, numeral 19 a circulating inlet to the circulating circuit 13, numeral 20 a shoot for exhausting improved powder, numeral 21 a cyclone, numeral 22 a rotary valve, numeral 23 a bag filter, numeral 24 a rotary valve, numeral 25 a wind exhausting device, numeral 31 a time control device for controlling operation of the apparatus of the present invention and numeral 32 a known pre-processor such as a various mixers and an electric mortar used in the case where it is necessary to adhere child particles to surface of mother particles previously.

Operation of the above apparatus is now described when the method of the present invention is implemented using the apparatus.

The valve 9 is closed and the rotary shaft 6 is driven by drive means not shown to rotate the rotating plate 4 at a peripheral speed of 5 m/sec to 160 m/sec depending on nature of material of which surface quality is to be improved while introducing inert gas into the apparatus if necessary. At this time, rotation of the impact pins 5 disposed around the rotating plate 4 produces a sudden current of air and inert gas. A circulating air current, that is, a current of air of perfect self-circulation type is formed from the circulating inlet 19 of the circulating circuit 13 which is formed in the impact chamber 18 through the circulating circuit 13 to the center of the rotating plate 4 by a fan effect based on a centrifugal force of the air current. Further, since air quality produced by circulation per unit time is extremely much as compared with the whole capacity of the impact chamber and the circulation system, very large circulation air current cycles are formed in a short time.

Then, powder to be processed which includes child particles adhered to surfaces of mother particles of a constant quality by utilizing, for example, electrostatic phenomenon is fed from the metering feeder 16 into the hopper 14 in a short time. In the case where it is not necessary to use the pre-processor 32, mother particles and child particles are measured separately and are fed into the hopper 14. The powder to

be processed enters from the hopper 14 through the shoot 15 to the impact chamber 18. The powder particles entered into the impact chamber 18 receive momentary strike by many impact pins 5 provided on the plate 4 rotating at a high speed and further collide with the collision ring 8, so that child particles adhered on surface of mother particles selectively receive strong compression. The powder to be processed enters into the circulating circuit 13 together with current of the circulating gas and is returned to the impact chamber 18, so that the powder particles are struck again.

Such impact operation is continuously repeated many times in a short time. The child particles are embedded or strongly fixed in the surface of the mother particles. The series of impact operation, that is, embedding or fixing operation of the child particles to surface of the mother particles continues until the whole surface of the mother particles is settled uniformly and firmly. Since much gas (that is, air and inert gas) as compared with the total capacity of the impact chamber and the circulating system is circulated in the system, the powder to be processed (mother particles and child particles) which circulates together with gas receives vast impacts in a very short time. The time requied to settle the surface of the particles is very short time such as several seconds to several minutes generally even if containing a time for supplying the powder, although depending on a quality of the powder to be processed at one time.

Figs. 1(1) and (2) illustrate a mother particle a to which only child particles b or both of child particles b and different child particles c are previously adhered by static electricity. When the particles are subjected to the fixing operation described above, the child particles b are enbedded in the mother particle a or fixed to the mother particle a as shown in Figs. 1(3) to (5) and the child particles b and c are fixed to the mother particle in the form of a single layer or plural layers by changing the order of supply of the child particles b and c, as shown in Figs. 1(6) to (8).

After completion of the above fixing operation, the valve 9 is moved to a position shown by chain line to open the valve 9 and the processed powder is exhausted. That is, the processed powder is exhausted from the impact chamber 18 and the circulating circuit 13 in a short time (several seconds) by centrifugal force (if the processed powder receives the centrifugal force, the valve 9 may be formed at another place) and sucking force of the wind exhausting device 25 and is guided through the shoot 20 to a powder collecting device such as the cyclone 21 and the bag filter 23. The guided powder is collected thereto and exhausted outside through the rotary valves 22 and 24.

After the processed powder has been exhausted, the valve 9 is closed immediately. Then, a constant quality of powder to be processed is fed to the impact chamber through the metering feeder 16 again. The powder is subjected to the fixing operation in the same manner so that the processed powder is manufactured successively. The fixing operation of powder in one operation is continuously controlled by the time control device 31 in which time required to process the powder has been established previously in relation to operating time of associating devices.

When it is required to fix child particles to surface of mother particles partially or locally, the powder impact apparatus of Fig. 2 can be used as a one pass type continuous processing system. In this case, the circulating inlet 19 is closed and the valve 9 is opened. Then, the powder to be processed may be fed from the hopper 15 continuously.

When it is required to use thermal treatment secondarily during the fixing operation (for example, when it is necessary to increase a difference of hardness between mother particles and child particles), the collision ring 8 and the circulating circuit 13 are formed in jacket structure and a temperature condition suitable for the fixing operation of powder can be set by means of various heating agent and refrigerant.

In the powder impact apparatus of the present invention, auxiliary blades can be mounted to the rotating plate 4 or a centrifugal type plate fan, for example, can be disposed on the way of the circulating circuit 13 so that forced power can be added to circulating current. More particularly, if air quality for circulation is increased, the number of times of circulation in unit time is increased. Accordingly, since the number of times of collision of powder is also increased, time required for the fixing operation can be reduced. Further, the method according to the present invention can be not only implemented by the apparatus provided with the circulating circuit but also by that having a structure in which the circulating circuit is removed in Figs. 2 and 3.

Description is now made to a case where various inert gas such as nitragen gas is used in order to prevent derioration due to oxidation during the fixing operation of the powder and to prevent production of fire and explosion in the surface improving operation or the fixing operation of powder performed by the powder impact apparatus of the present invention.

Fig. 4 shows an embodiment in which inert gas is used in the powder impact apparatus according to the present invention. In this embodiment, like elements to that of Figs. 1 and 2 are designated by like numerals and description thereof is omitted. In Fig. 4, numeral 26 denotes a valve disposed below the hopper 14 to feed raw material, numeral 27 denotes a valve coupled with an opening formed in the shoot 15 to supply inert gas, numeral 28 denotes an inert gas supply source, and numeral 29 denotes a path for supplying inert gas. In this embodiment, the circulating circuit 13 is provided within the casing 1.

At the beginning of operation, the valve 26 for feeding raw material is closed and the valve 9 is opened. Then, the valve 27 for supplying inert gas is opened so that the impact chamber 18 and the circulating circuit 13 are filled with inert gas. The filling operation of inert gas in the impact chamber and the circulating circuit prior to the fixing operation is generally terminated within a few minutes.

After the valves 9 and 27 are then closed simultaneously, the valve 26 is opened immediately so that previously measured powder is fed through the shoot 15 to the impact chamber 18. After supply of powder, the valve 26 is closed immediately. In response to the closure of the valve 26, the metering feeder 16 measures powder for the next operation and supplies it to the hopper 14.

The powder is then subjected to the impact operation together with inert gas in the same manner as in the above embodiment of Fig. 2. The powder is settled while circulating in the circuit 13 and maintaining in sufficient contact with inert gas. The valves 9 and 27 are then opened and the processed powder is exhausted from the impact chamber 18 and the circulating circuit 13 to shoot 20. At the same time, the impact chamber 18 and the circulating circuit 13 are filled with new inert gas. The exhausted powder is processed in the same manner as in the embodiment of Fig. 2.

Then, when the valves 9 and 27 are closed and the valve 26 is opened, the subsequent fixing operation is started. The series of fixing operation including supply and stop of inert gas is continuously controlled by the time controlled device 31 in the same manner as the embodiment of Fig. 2.

If child particles may be fixed to surface of the mother particles partially, the powder impact apparatus of Fig. 4 can be used as a one pass type continuous processing system. In this case, the circulating circuit 13 of Fig. 4 is closed and the valves 26, 27 and 9 are opened. The powder to be processed may be fed from the hopper 14 continuously at a rate of constant quality. At this time, if inert gas from the outlet of the wind exhausting device 25 of Fig. 2 is returned to the shoot 15, a quality of used inert gas can be reduced economically.

As described above, the surface quality improving method of solid (powder) particles and the apparatus thereof according to the present invention are characterized by strong impact of the impactor mechanism forming the impact striking means to fine powder particles, utilization of difference of hardness between mother particles and child particles, magnitude of impact given to the whole surface of mother particles having a fixed shape, and the number of times of impact which can be adjusted.

Further, as described above, according to the method and apparatus of the present invention, child particles are formed on surface of the mother particle made of various material in the form of a single layer made of a single component of child particles and made of two components and in the form of a plurality of layers made of one or more components of child particles.

According to the method and the apparatus of the present invention, if a ratio of fixed child particles to each mother particle may be not severe so much (that is, if a ratio of component as a whole may be constant), the pre-processor such as various mixers and an electric mortar is not used and mother particle powder and child particle powder measured separately are supplied to the impact chamber directly so that the fixing operation of child particles to surface of mother particles can be made.

As described above, according to the surface quality improving method of solid particles and the apparatus thereof according to the present invention, quality of surface of mother particles composed of combination of various powder materials is improved by embedding or firmly fixing child particles to the surface of mother particles and functional composite and hybrid powder having uniform and stable characteristics can be produced effectively in a very short time.

The surface quality improving apparatus of solid particles according to the present invention includes the impact chamber and the circulating circuit having very simple structure and when the front cover is opened the rotating plate 4 can be removed to make disassembly easily. Accordingly, maintenance and cleaning in the apparatus can be made very easily. The apparatus can be avoid mixture of alien material upon change of a product and can be provided to improve quality of surface of powder material of wide range.

Further, when inert gas is used, inert gas is used efficiently and quality of used inert gas can be minimized.

EXAMPLE 1

The powder impact apparatus of Fig. 2 including eight plate type impact pins mounted on the periphery of the rotating plate and having an outer diameter of 235 mm and the circulating circuit having a diameter of 54.9 mm was used. Child particles made of titanium dioxide having average diameter of dp50 = 0.3μm were previously adhered to surface of mother particles 12 made of spherical nylon having average diameter of dp50 = 5μm by a mixer to make ordered mixture which was fixed or settled under processing condition shown in Table 1. Consequently, titanium dioxide (child particles) was embedded or firmly fixed to surface of nylon 12 (mother particles), and uniform and stable powder of nylon 12 of which quality of surface was improved by titanium dioxide can be obtained.

Fig. 5 shows photographs taken by a scanning electon microscope of improved powder obtained by the Example 1 (T-3 and T-4).

TABLE 1

Fixing condition of titanium dioxide to nylon 12 (sphere) forming a core.

	IMPLEMENTATION NO.			
	T-1	T-2	T-3	T-4
ROTATIONAL NO. OF ROTARY PLATE(r/m)	9385	9385	9385	6540
PIN PERIPHERAL SPEED (m/s)	115.5	115.5	115.5	80.5
CIRCULATING WIND QUANTITY (m^3/min)	3.3	3.3	3.3	2.3
NO. OF TIMES OF CIRCULATION	1158	1158	3474	2418
SUPPLY QUANTITY OF POWDER (g)	70	35	35	35
PROCESSING TIME (min)	2	2	6	6
TEMPERATURE OF POWDER (° C)	120	80	112	68
DECISION OF QUALITY	good	good	good	good

(Note) The above number of times of circulation was calculated from capacities of the impact chamber and the circulation circuit on the basis of the measured circulating wind quantity.

A second embodiment of the present invention is now described.

Representative mother particle powder uses various powder shown in the first embodiment. Generally, representative child particle powder has a diameter of about 0.01 µm to 10 µm and contains nylon powder, polyethlene powder, acryl powder, styrene powder, polypropylene powder, ABS powder, polyvinyl alcohol, gelatin, various wax, sulfur and organic substance, inorganic substance and metal such as alloy having low melting point. However, it is not limited to these material in the same manner as the first embodiment. Combination of sizes of a diameter and magnitude of hardness is the same as the first embodiment.

Impact striking means uses the same impactor as the first embodiment shown in Figs. 2 to 4 and operation is made in the simmilar manner.

Impact operation is continuously repeated many times in a short time, and child particles are embedded or firmly fixed to surface of mother particles. Further, child particles receive thermal energy by impact operation to soften and melt in a short time, so that the whole or part of child particles fixed to surface of one mother particle are melted and united to each other. The series of impact operation, that is, the softening, melting and fixing operations of child particles to surface of mother particle are continued until the whole surface of mother particle becomes a desired melted and united condition.

Fig. 6 shows models. In figure, mother particles and child particles are not limited to sphere. Figs. 6(1) and (2) illustrate mother particle (a and a') to which child particles (b and b') are adhered previously by static electricity. The mother and child particles are subjected to the impact striking operation and surface of child particles is softened and melted as shown in Figs. 6(3) to (5). Union or combination between child particles is caused at partial surface or over the whole surface of mother particle so that child particles are settled to surface of mother particle. Further, as shown in Figs. 6(6) to (8), child particles (b, c) different from each other are fixed to mother particle a in the form of a single layer or multiple layers depending on combination of various child particles and supply order of child particles.

As shown in Fig. 6, according to the method of the present invention, child particles are fixed to surface of mother particle made of various material in the form of a single particle layer composed of a single component of child particles or composed of two component of child particles, in the form of a micro capsule formed by covering mother particle in the form of film with child particle and a plurality of layers composed of one component or more of child particles. The child particles may be any shape such as sphere, indeterminate form, fiber shape and the like.

The surface of mother particle is not limited to smooth surface and may be any shape having, for example, various sizes of uneven portions, holes or grooves.

If child particles may be fixed to surface of mother particle partially and locally, if thermal treatment is used secondarily, if inert gas is used, or the like, the fixing operation may be made in the same manner as the first embodiment.

EXAMPLE 2

The same apparatus as the example 1 is used. The child particles of PMMA (polymethyl methacrylate) having average diameter of dp50 = 0.3μm are adhered. to surface of mother paticle of spherical nylon 12 having average diameter of dp50 = 5μm by a mixer previously to form ordered mixture, which is subjected to fixing operation including softening and melting operation under processing condition shown in Table 2. Consequently, child particles of polymethyl methacrylate are embedded in or firmly fixed to surface of mother paricle forming core of nylon 12, and part or the whole of child particles are soften and melted, so that child particles are fixed to surface of mother particle. Thus, powder of nylon 12 having surface improved uniformly and stably by polymethyl methacrylate was obtained. Differences of softing and melting conditions for child particles depending on operating conditions are clearly shown (refer to photographs taken by a scanning electron microscope of Fig. 7). If mother particle in the form of micro capsule is desired (refer to Fig. 7(2)), it can be obtained under condition of T-11.

TABLE 2

Softening, melting and fixing condition of polymethyl methacrylate to nylon 12 (sphere) forming a core.

	IMPLEMENTAION NO.		
	T-11	T-12	T-13
ROTATIONAL NO. OF ROTARY PLATE(r/m)	9385	6540	6540
PIN PERIPHERAL SPEED (m/s)	115.5	80.5	80.5
CIRCULATING WIND QUANTITY (m^3/min)	3.3	2.3	2.3
NO. OF TIMES OF CIRCULATION	1158	806	2418
SUPPLY QUANTITY OF POWDER (g)	35	35	35
PROCESSING TIME (min)	2	2	6
TEMPERATURE OF POWDER (° C)	84	56	65
DECISION OF QUALITY	melted wholly	melted partially	

(Note) The above number of times of circulation was calculated from capacities of the impact chamber and the circulation circuit on the basis of the measured circulating wind quantity.

Fig. 7 shows photographs taken by a scanning electron microscope of improved powder obtained by the example 2.

Fig. 7(1) shows child particles adhered to surface of mother particle, Figs. 7(2), (3) and (4) show particles improved under conditions of the implementation Nos. T-11, T-12 and T-13, respectively.

A third embodiment of the present invention is now described.

Generally, representative mother particle powder processed by the method of the present invention has a diameter of about 0.1 µm to 100 µm and contains inorganic substances such as calcium carbonate, kaolin, alumina, silica, glass bead and titanium dioxide, metal and metal compound such as copper, lead, zinc, tin and iron, organic substance composite high molecule material such as epoxy powder, nylon powder, polyethylene powder and polystyrene powder, and organic substance natural material such as starch, cellulose and silk powder. Further, representative metal child particle powder (containing particle in the form of needle and thread) has generally a diameter of about 0.01 µm to 10 µm and contains fine particle powder formed of gold, silver, copper, zinc, tin, iron, lead, stainless steel, nickel, aluminium, titanium and cadmium, and powder oxide and compound powder thereof. However, both particles are not limited to the above materials and are applicable to combined components of various materials used in industries such as chemical industry, electrical industry, magnetic industry and varous other industries dealing with cosmetics, paints, printing ink, toner, color material, fiber, medicine, foods, rubber, plastic, ceramic and the like.

There are generally used mother particles having large diameter and child particles having small diameter. However, relation of the diameter between mother particles and child particles is reversed depending on combination of largeness of particles.

Impact striking means uses the same impactor as in the first embodiment shown in Figs. 2 to 4 and the sililar operation is made. Further, there is a case where child particles are adhered to surface of mother particles while using a small quality of water or material forming a binder such as various organic solvent.

Impact operation is continuously repeated many times in a short time so that metal child particles are strongly beaten out to surface of mother particle. Further, the metal child particles are firmly fixed to surface of mother particles in a short time by receiving thermal energy due to impact operation. The series of impact operation, that is, the beating and fixing operation of metal child particles to surface of mother particle is continued until surface of mother particle becomes desired beaten and fixed condition locally or wholly. Since gas (containing air and inert gas) having large quality as compared with all the capacity of the impact chamber and the circulating system is circulated in the system, particle (that is, mother particles and metal child particles) circulating in the system together with gas receives very large number of times of impact in a very short time. The time required to the beating and fixing operation is as very short as several seconds to several minutes even if containing supply time of powder to be processed, although depending on quality of powder to be processed at one time.

Description is made using figures of the second embodiment. As shown in Figs. 6(1) and (2), metal particles (b, b´) are adhered to mother particle with static electricity or small quality of binder previously. The mother particles and child particles are subjected to the impact operation to beat out surface of metal child particles as shown in Fig. 6(3) to (5) so that metal child particles are adhered or overlapped to each other partially or wholly and metal child particles are fixed to surface of mother particle. Further, metal child particles (b, c) different from each other can be beaten and fixed to surface of mother particle in a single layer and multiple layers depending on combination of various metal child particles and supply order thereof.

Further, if metal child particles may be fixed to surface of mother particle partially and locally, if thermal treatment is used secondarily, if inert gas is used, or like, the operation may be made in the same manner as the embodiment.

As described above, the method of beating and fixing metal particles to surface of solid particles according to the present invention is characterized by adjustability of the magnitude of impact and the number of times of impact given to metal particles adhered to the whole surface of mother particle having a fixed shape under a condition where fine powder particles are perfectly dispersed in air in the apparatus by utilizing strong impact of the impactor forming the impact striking means to fine powder particles. Since proper impact can be given to individual fine powder particles simultaneously while preventing perfectly various fine powder particles having a diameter of the order of micron and tendency of cohering with each other from being adhered to each other, the improved powder having uniform quality and excellent color and brightness peculiar to metal can be produced in a short time.

As described above, according to the method of the present invention, metal child particles are beaten out and fixed to mother particles of various material in a single layer made of a component of metal child particles or two or more components of metal child particles, in the form of micro capsule covering mother particle like film, and in plural layers made of one or more components of metal particles. The metal particles may be any shape such as sphere, indeterminate form, fiber shape and the like.

As described above, according to the method of the present invention, the metal child particles are beaten out and fixed to the mother particles made of combination of various powder material so that quality of surface of mother particle is improved, and functional composite or hybrid having uniform and stable characteristics can be produced effectively in a very short time.

EXAMPLE 3

The same apparatus as that used in the examples 1 and 2 is used.

Silver powder particles for conductive paint having average diameter of dp50 = 0.5µm to 3µm are adhered to surface of mother particle made of spherical nylon 12 having average diameter dp50 = 15µm previously to form ordered mixture, which has been beaten out and fixed under processing condition shown in Table 3. Consequently, in any cases, silver powder particles (metal child particles) have been beaten out and fixed to surface of mother particle of nylon 12 forming core, and uniform and stable surface quality improved powder of nylon 12 by silver powder for conductive paint was obtained.

TABLE 3

Extending and fixing condition of silver powder for conductive paint to nylon 12 (sphere) forming a core.

	IMPLEMENTATION NO.	
	T-21	T-22
ROTATIONAL NO. OF ROTARY PLATE(r/m)	9385	6540
PIN PERIPHERAL SPEED (m/s)	115.5	80.5
CIRCULATING WIND QUANTITY (m^3/min)	3.3	2.3
NO. OF TIMES OF CIRCULATION	1158	806
SUPPLY QUANTITY OF POWDER (g)	50	50
PROCESSING TIME (min)	4	6
TEMPERATURE OF POWDER (° C)	88	67
DECISION OF QUALITY	good	good

(Note) The above number of times of circulation was calculated from capacities of the impact chamber and the circulation circuit on the basis of the measured circulating wind quantity.

A fourth embodiment of the present invention is now described. Representative mother particle powder uses various powder described in the third embodiment. Further, representative child particle powder contains inorganic matter such as calcium carbonate, kaoline, alumina and titanium dioxide, metal and metal compound such as copper, zinc, tin and iron, organic matter such as nylon, acryl, styrene and ABS in the form of a suspension, emulsion, sol and gel and having a diameter of about 0.001 µm to 10 µm. Melting material for forming a film contains wax, paraffin, rosin, various cellulose, oils and fats, gelatin, sugar, rubber, starch, starch inductor, silicon, titanium dioxide, copper, silver and various inorganic salts in the

form of melted liquid. However, they are not limited to the above materials and are applicable to combined components of various materials used in industries such as chemical industry, electrical industry, magnetic industry and various other industries dealing with cosmetics, paints, printing ink, toner, color material, fiber, medicine, foods, rubber, plastic, ceramic and the like.

Figs. 9 and 10 shows an impactor used in the embodiment, in which numerals 32a, 32b and 32c denote, for example, spray nozzles for supplying liquid, that is, suspension or solution to surface of mother particle, numeral 33 denotes supply pipes of the liquid, numeral 34 denotes supply pumps of the liquid, numeral 35 denotes a reservoir of the liquid, numeral 36 denotes valves of the liquid which open and close automatically and manually. Other elements are the same as those of the apparatus shown in the above embodiment and are designated by like numerals and description is omitted.

Circulation cycle of air current are formed in the apparatus in the same manner as in the above embodiment.

A constant quality of powder to be processed, that is, mother particles are supplied to the hopper 14 from the metering feeder 16 in a short time. At the same time or after the lapse of a constant time - (generally, several seconds to several minutes) since the mother particles have been supplied to the hopper 14, solution such as suspension, emulsion, sol and gel containing small particles for surface quality improvement or solution of material for surface quality improvement is supplied from the nozzles 32a, 32b and 32c. Whether the solution is supplied from a plurality of nozzles 32 or from one of nozzles 32 is determined depending on combination of materials or others. Supply quality of the solution is set by, for example, established pressure of the pump 34 and opening and closing time of the automatic valve. The powder to be processed is supplied from the hopper 14 through the shoot 15 to impact chamber 18 and the solution supplied from the nozzles 32a, 32b and 32c is also supplied to the impact chamber 18. The powder particles and solution supplied to the impact chamber 18 receive momentary striking operation by multiple impact pins 5 mounted on the rotating plate 4 which rotates at a high speed and collide against the collision ring 8 provided peripherally so that surfaces of mother particles are compressed strongly. The powder is returned through the circulating circuit 13 to the impact chamber 18 again together with a current of the circulating gas and are struck again.

The impact operation is continuously repeated proper times in a short times. Thus, solution is uniformly adhered to surface of mother particles and the adhered solution receives thermal energy caused by impact operation. The solution containing child particles is dried in a short time and at the same time child particles left to surface of mother particles are firmly adhered to mother particles. In the similar process, solid matter in solution is also fixed to surface of mother particles. Solution having high temperature upon supply is reversely cooled and melted material forms film on surface of mother particles. The series of impact operation, that is, fixing operation of child particles to surface of mother particle or film forming operation of melted material is continued until the whole surface of mother particle becomes desired condition. Since large quality of gas (air and inert gas) as compared with the whole capacity of the impact chamber and the circulating system is circulated in the system, powder to be processed (mother particles and child particles or film forming material) circulating together with gas receives impacts by very large number of times in a very short time. Accordingly, even if fine powder having a diameter of the order of micron and tendency of cohering to each other is adhered to surface of mother particle together with solution, particles are perfectly prevented from adhering and cohering to each other by the strong impact and very large number of times of impact and at the same time proper impact is given to individual fine particles. The operation terminates in a very short time in the same manner as the above embodiment.

Fig. 8 shows models. In figure, mother particles and child particles are not limited to sphere. Figs. 8(1) and (2) illustrate mother particles (a, a´) with child particles (b, b´) adhering to the mother particles together with various solutions (c), and Fig. 8(3) illustrates mother particles (a´´) to which solution (d) of various materials adheres. The mother particles, child particles and solutions are subjected to the impact operation. Thus, as shown in Figs. 8(4) to (7), the solution (c) containing child particles is dried and solution is dried or cooled so that at the same time child particles or film is firmly fixed to surface of mother particles. The child particles (b, e) different from each other are fixed to surface of the mother particles (a) in a single and multiple layers and multiple layers of films (d, f) can be fixed to surface of mother particles (a´´) depending on combination of various child particles and supply order as shown in Figs. 8(8) to (11).

Other operation may be performed in the same manner as the above embodiments.

If child particles are fixed to surface of mother particles partially and locally and if thermal treatment is used secondarily, the operation is made in the same manner as the above embodiment.

Description is now made to a case where various inert gas such as nitragen gas is used in order to prevent derioration due to oxidation during the fixing operation of the powder and to prevent production of fire and explosion in the surface improving operation of powder performed by the powder impact apparatus of the present invention.

Fig. 11 shows an embodiment of the powder impactor according to the present invention in which inert gas is used. Like elements to those of the above embodiment are designated with like numeral and description thereof is omitted.

At the beginning of operation, the valve 26 for feeding raw material is closed and the valve 9 is opened. Then, the valve 27 for supplying inert gas is opened so that the impact chamber 18 and the circulating circuit 13 are filled with inert gas. The filling operation of inert gas in the impact chamber and the circulating circuit prior to the fixing operation is generally terminated within a few minutes.

After the valves 9 and 27 are then closed simultaneously, the valve 26 is opened immediately so that previously measured powder is fed through the shoot 15 to the impact chamber 18. At the same time or after a constant time, liquid is supplied from the nozzles 32b and 32c. After supply of powder, the valve 26 is closed immediately. In response to the closure of the valve 26, the metering feeder 16 measures powder for the next operation and supplies it to the hopper 14.

The powder is then subjected to the impact operation together with inert gas in the same manner as in the above embodiments and is processed in the same manner as in the above embodiments. The resultant effects are substantially identical.

In the method of the present invention, since proper impact can be given to individual fine powder while preventing various fine powder having a diameter of micron and tendency of cohering to each other from adhering to each other, functional improved powder having uniform quality can be produced in short time.

As shown in Fig. 8, according to the method of the present invention, child particles or film forming material is fixed to surface of mother particle of various material in a single layer made of one component or two or more components of child particles, in the form of micro capsule in which mother particles are covered with film, and in plural layers made of one or more components of child particles or film forming material.

As described above, according to the surface quality method of solid particles and the apparatus thereof according to the present invention, child particles or film forming material is firmly fixed to mother particles composed of combination of various powder material and liquid so that quality of surface of mother particles is improved, and functional composite or hybrid powder having uniform and stable characteristics can be produced effectively in a very short time.

EXAMPLE 4

A powder impactor of Fig. 9 including eight plate type impact pins mounted in the periphery of the rotating plate and having an outer diameter of 235 mm and circulating circuit having a diameter of 54.9 mm is used. Child particles made of titanium dioxide having an average diameter of dp50 = 0.3µm and contained in suspension formed by suspending titanium dioxide in water having quality of 1.2 times titanium dioxide in weight ratio are fixed to surface of mother particles of spheric nylon 12 having an average diameter of dp50 = 5µm. Under the fixing condition of rotational number of plate = 9385 r/m, outer pheripheral speed of plate type impact pins = 115.5 m/s, circulating wind quality = 3.3 m³/min, number of time of circulation = 2895 times and processing time = 5 min, powder having supply quality of 35g and suspension having supply quality of 19g are supplied intermittently in four minutes at the beginning and are subjected to the fixing operation. Consequently, titanium dioxide of child particles is embedded and fixed to surface of nylon 12 of mother particles. Thus, as shown in Fig. 8(4), the surface quality improved powder by titanium dioxide of nylon 12 having uniform and stable characteristics was obtained. Further, water contained in the obtained surface quality improved powder was measured (at a temperature of improved powder of 79°C) and it was understood that it was in substantially perfect dry state.

EXAMPLE 5

The powder impactor of Fig. 9 including twelve plate type impact pins mounted in the periphery of the rotating plate and having an outer diameter of 235 mm and circulating circuit having a diameter of 54.9 mm is used. In order to make film of wax melted at a temperature of 80°C on surface of mother particles made of starch of potato and having an average diameter of 60 -80 µm, the improving operation was effected

under the following filming conditions. Under the conditions of rotational number of rotating plate = 6540 r/m, outer peripheral speed of plate type impact pin = 80.5 m/s, circulating wind quality = 2.3 m^3 /min, circulating number of times = 1209 times and processing time = 3 min, powder (starch) having supply quality of 40g and melted wax having supply quality of 10g were supplied continuously in two minutes at the beginning and film forming operation was made. Consequently, cooled wax is formed in film over the whole surface of starch particle and micro capsule formed of wax of starch particle having uniform and stable characteristics was obtained as shown in Fig. 8(7).

In the improving operation, the outer wall of the impact chamber and the circulating pipe was formed in jacket structure in order to reduce a temperature of circulating air to 65 °C or less and cooling water having a temperature of 14°C was used as refrigerant. Consequently, temperature of obtained improved powder was 54°C.

A fifth embodiment of the present invention is now described.

Representative mother particle powder of which surface can be processed by the method of the present invenion has a diameter of about 0.1 µm to 100 µm and surface formed in various shape with uneven portions, holes and grooves and is formed of organic matter, inorganic matter and metal such as nylon powder, polyethylene powder, acryl powder, styrene powder, ABS powder, polypropylene powder, gelatin, various wax, sulfur, copper powder and silver powder. Representative child particle powder has a diameter of about 0.01 µm to 10 µm and is formed of pigment such as titanium dioxide, carbon and iron oxide, high molecule material such as epoxy powder, nylon powder and acryl powder, metal such as tin, silver and copper, natural material such as starch, cellulose, silk powder and ceramics and various powder perfume. However, the present invention is not limited to the above materials and is applicable to combined components of various materials used in industries such as chemical industry, electrical industry, magnetic industry and various other industries dealing with cosmetics, paints, printing ink, toner, color material, fiber, medicine, foods, rubber, plastic, ceramic and the like.

The same impactor as that of the above embodiment shown in Figs. 2 to 4 is employed as impact striking means and operation is performed in the same manner.

The impact operation is continuously repeated proper times in a short time. Surface of mother particles, particularly projections of mother particles receive thermal energy caused by impact operation so that projections are soften, melted and transformed and child particles are embedded in mother particles. Thus, film of mother particles is formed on surface of mother surface. The series of impact operation is continued until the whole surface of mother particles becomes desired melted state. The time required to improve quality of surface is generally very short time of several seconds to several minutes even if containing supply time of powder in the same manner as in the above embodiments.

Fig. 12 shows models. In Fig. 12, a represents a mother particle having a surface formed in various shape of uneven portions or with holes and grooves and b represents child particles. Fig. 12(1) shows mother particle and child particles both being not adhered to each other, and Fig. 12(2) shows mother particle with child particles being adhered to the mother particle. When the mother particle with child particles adhered is subjected to the impact operation, portions, that is, projections of the mother particle are softened, melted or transformed and child particles are embedded into mother particle as shown in Figs. 12(3) and (4). The embedded child particles are not limited to a single component of child particles but can contain two or more components of child particles. The subsequent operation is the same as that of the above embodiment.

If child particles may be fixed to surface of mother particle partially and locally, if thermal treatment is used secondarily, if inert gas is used, or like, the same operation as in the first to third embodiments may be made.

As described above, the surface quality improving method of solid particle powder accoring to the present invention is characterized by strong impact of the impactor mechanism forming impact striking means to fine powder particles and embedment of child particles into mother particle by utilization of impact in view of surface shape of mother particle.

EXAMPLE 6

The powder impactor of Fig. 2 including eight-plate-type impact pins mounted in the periphery of the rotating plate and having an outer diameter of 235 mm and the circulating circuit having a diameter of 54.9 mm was employed. Child particles of acetylene black having an average diameter of dp50 = 0.03µm were mixed and adhered to mother particles of porous nylon 6 having an average diameter of dp50 = 19µm by a

mixer. The particles adhered to each other were processed by the processing apparatus under the conditions of rotational number of 6540 rpm, powder supply quality of 120g and operating time of 2 minutes. Surface quality improved powder in which embedded acetylene black (child particles) into nylon particle (mother particle) is further covered over surface thereof with nylon 6 was obtained.

Fig. 13 shows photographs taken by a scanning electron microscope of powder sample used in the embodiment, in which Fig. 13(1) shows porous mother particles, Fig. 13(2) shows mother particle with child particles adhering to mother particle, and Fig. 13(3) shows mother particle in which child particles are embedded.

As described above, according to the surface quality improving method of solid particle according to the present invention, the surface quality improving operation in which child particles are embedded into mother particle composed of combination of various powder materials by utilizing shape of surface of mother particle is performed so that functional composite or hybrid powder having uniform and stable characteristics can be obtained efficiently in a very short time.

The method of spheroidizing solid particles by the apparatus of the present invention is now described.

Heretofore, the spheroidizing operation of fine powder is made in order to prevent lumping of solid particles and to improve dispersion and fluidity. The operation has been made by putting material into an agitator of various mixer type and ball mill type to agitate the material for a long time (generally, several hours to several tens hours) and by giving friction force and compression force caused by agitation.

However, it takes several hours to several tens hours to obtain desired spherical particles and accordingly the apparatus therefor is large in size. Furthermore, friction force and compression force caused by agitation are effected to fine particles having different diameters uniformly. Accordingly, most of particles to be spheroidized are broken or are formed in flat, and quality and working efficiency are deteriorated.

The embodiment provides the method in which fine solid particles having different diameters and shape as shown by a phothgraph (1) of Fig. 14 can be made to spherical particles having uniform roundness as shown by a photograph (2) of Fig. 14 by using mechanical impact means and if necessary using thermal means as auxiliary means in a very short time. The gist thereof resides in the method of spheroidizing indeterminate fine solid particles (powder) by using impact striking means.

Representative powder to be spheroidized has a diameter of about 0.1 µm to 100 µm and is formed of organic matter such as epoxy powder, nylon powder, polyethylene powder, polystyrene powder, cellulose and silk powder, inorganic matter and metal such as titanium oxide, graphite, zinc powder, nickel, copper, lead and iron. However, the powder is not limited to the above materials and is applicable to combined components of various materials used in industries such as chemical industry, electrical industry, magnetic industry and various other industries dealing with cosmetics, paints, printing ink, toner, color material, fiber, medicine, foods, rubber, plastic, ceramic and the like.

As described in the above embodiments, when the core is formed by various materials and fine particles having characteristic different from that of the core particle are fixed to surface of the core particle or are formed in film on surface of the core particle, that is, when the surface quality improving operation is made, if the core material has indeterminate shape (generally, diameter thereof is not uniform), the spheroidizing operation can be made at the same time as the surface quality improving operation.

With the apparatus, raw material to be spheroidized is supplied to the hopper 14 and the same operation as the above embodiments is made.

The impact operation is continuously repeated proper times in a short time and indeterminate powder particles are spheroidized. The series of impact operation, that is, spheroidizing operation is continued until the whole surface of fine powder particles becomes uniform sphere or substantially round. The spheroidizing operation is terminated in a very short time in the same manner as the embodiments.

If the particles are spheroidized partially and locally, if thermal treatment is used secondarily, if inert gas is used, or the like, the same operation as the above embodiments may be made.

EXAMPLE 7

The same powder impactor as that of the example 6 was used. Indeterminate styrene resin powder particles (Fig. 14(1)) having an average diameter of dp50 = 15µm are spheroidized under the processing condition shown in Table 4. Consequently, spherical powder particles having uniform roundness as shown in Fig. 14(2) were obtained.

TABLE 4

TABLE 4

Spheroidizing condition of indeterminate styrene resin powder

	IMPLEMENTAION NO.		
	T-31	T-32	T-33
ROTATIONAL NO. OF ROTARY PLATE(r/m)	9385	9385	6540
PIN PERIPHERAL SPEED (m/s)	115.5	115.5	80.5
CIRCULATING WIND QUANTITY (m^3/min)	3.3	3.3	2.3
NO. OF TIMES OF CIRCULATION	1158	1158	2418
SUPPLY QUANTITY OF POWDER (g)	100	65	100
PROCESSING TIME (min)	2	2	6
TEMPERATURE OF POWDER (° C)	70	62	68
DECISION OF QUALITY	good	good	good

(Note) The above number of times of circulation was measured from capacities of the impact chamber and the circulation circuit on the basis of the measured circulating wind quantity.

Fig. 14 shows photographs taken by a scanning electron microscope of powder particles before and after spheroidization under conditions of the example 7 (T-33).

As described above, according to the present invention, the magnitude of impact and number of times thereof for giving impact to the whole surface of powder particles having different diameters and shapes in the state where fine powder particles are dispersed perfectly in air of the system by utilizing strong impact of the impactor forming impact striking means to the fine particles can be adjusted properly.

Accordingly, since proper impact can be given to individual fine powder particles while preventing various fine powder particles having diameter of the order of micron and tendency of cohering to each other from adhering to each other, spherical particles having uniform roundness can be produced efficiently in a short time.

Claims

1. A method of improving quality of surface of solid particles, characterized in that other material different from that of said solid particles is fixed to the surface of said solid particles by using impact striking means.

2. A method according to Claim 1, characterized in that other solid particles are fixed to the surface of said solid particles by embedding or fixing said other solid particles by using the impact striking means.

3. A method according to Claim 1, characterized in that other solid particles are fixed to the surface of said solid particles by softening and melting said other solid particles by using the impact striking means.

4. A method according to Claim 1, characterized in that other metal solid particles are fixed to the surface of said solid particles by beating out said other metal solid particles by using the impact striking means.

5. A method according to Claim 1, characterized in that the impact striking means is employed to dry or cool liquid and to fix film of other fine solid particles contained the liquid or material forming the liquid to the surface of said solid particles.

6. A method according to Claim 1, characterized in that other solid particles are embedded in cavities of said solid particles having surface formed in various shapes containing uneven portions, holes or grooves and impact striking means is employed to soften, melt and transform said solid particles so that said other solid particles are wrapped to be fixed therein.

7. A method according to Claim 1, characterized in that other material is previously adhered to surface of said solid particles.

8. A method according to any one of Claims 2, 3 or 6, characterized in that auxiliary means is employed to heat and melt particles.

9. A method according to Claim 4, characterized in that auxiliary means is employed to heat and closely and firmly adhere said solid particles and said beaten particles.

10. A method according to Claim 5, characterized in that said liquid is supplied while giving impact to said solid particles so that said liquid is adhered to said solid particles.

11. A method according to Claim 5, characterized in that auxiliary means is employed to heat or cool said solid particles and dry or cool said liquid.

12. A method according to Claim 5, characterized in that said liquid is a solution containing fine solid particles or solution of various material.

13. A method according to Claim 1, characterized in that said method is performed in inert gas.

14. An apparatus for improving quality of surface of solid particles, characterized by the provision of an impact chamber provided with impact striking means, a supply inlet for feeding solid particles into said chamber, and a circulating path communicating between an outlet of said impact chamber and said supply inlet.

15. An apparatus according to Claim 14, characterized by the provision of a nozzle provided to at least one of said impact chamber, said supply inlet or said circulating path for feeding liquid.

16. An apparatus according to Claim 14 or 15, characterized by the provision of heating means.

17. An apparatus according to Claim 14 or 15, characterized by the provision of inert gas supply means.

18. An apparatus according to Claim 14 or 15, characterized by the provision of an impactor.

FIG. 1(1)

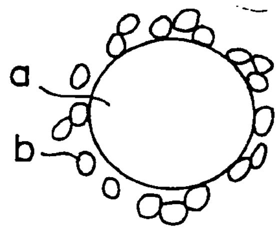


FIG. 1(2)

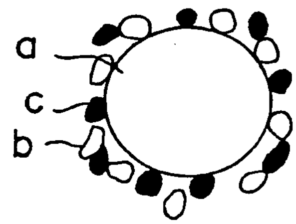


FIG. 1(3)

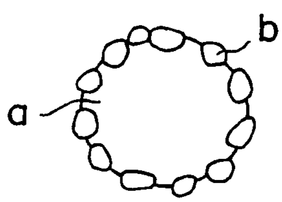


FIG. 1(4)

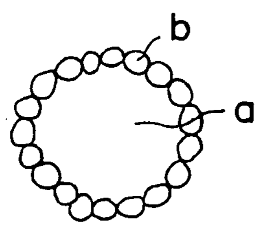


FIG. 1(5)

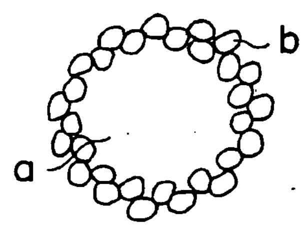


FIG. 1(6)

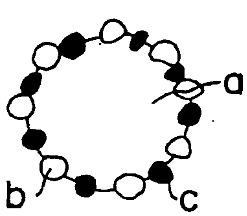


FIG. 1(7)

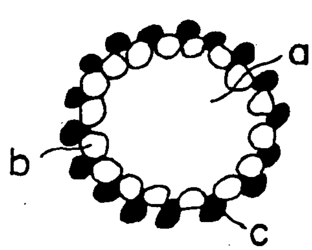
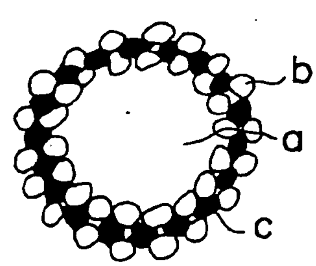
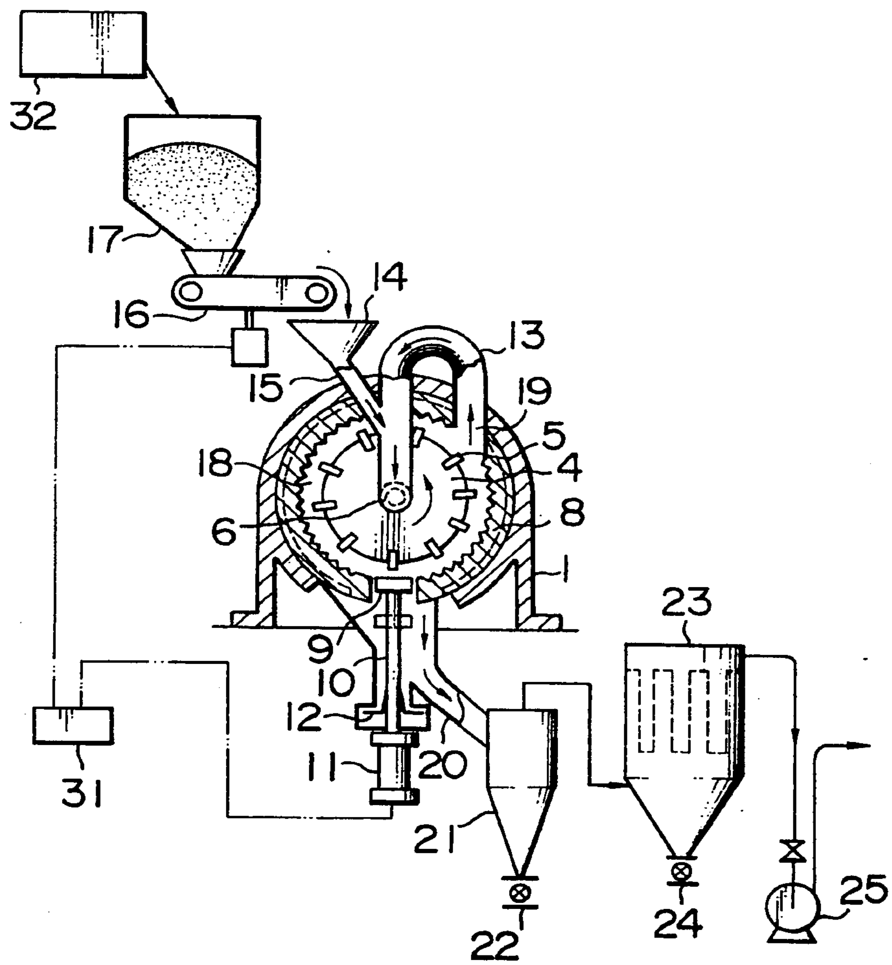


FIG. 1(8)





F I G. 2

FIG. 3

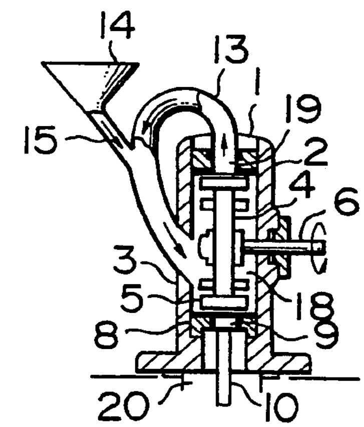


FIG. 4

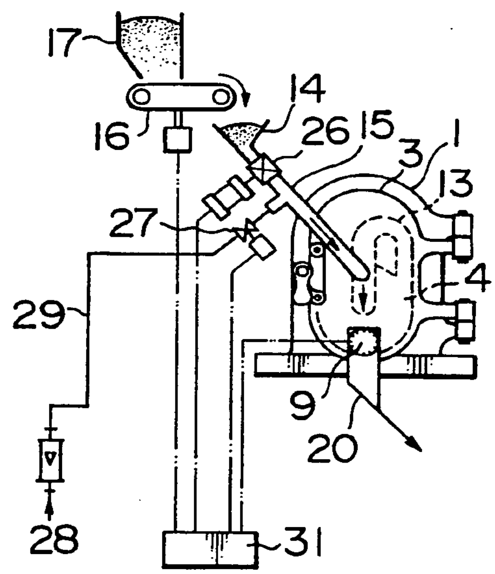


FIG. 5(1)

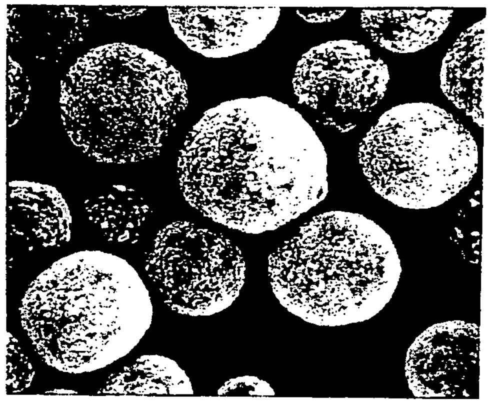


FIG. 5(2)

FIG. 5(3)

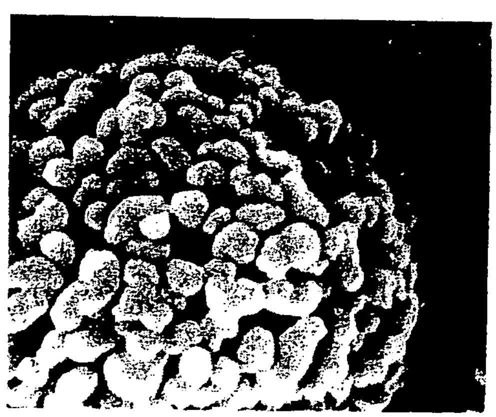


FIG.6(1)

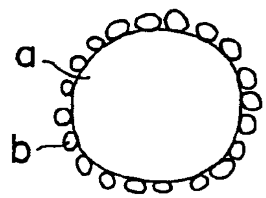


FIG.6(2)

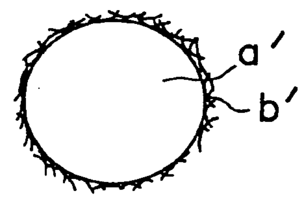


FIG.6(3)

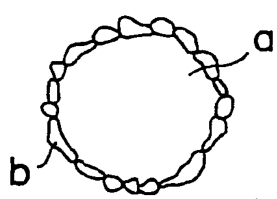


FIG.6(4)

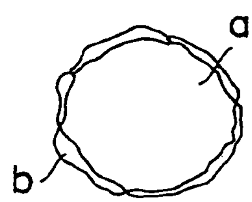


FIG.6(5)

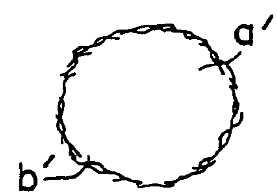


FIG.6(6)

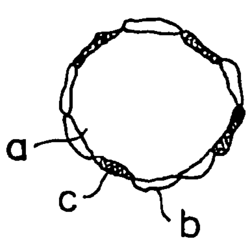


FIG.6(7)

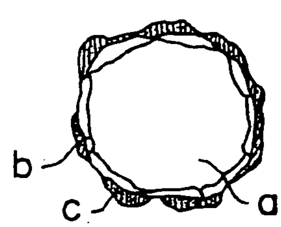


FIG.6(8)

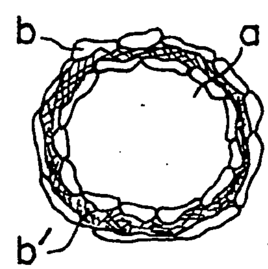


FIG. 7(1)

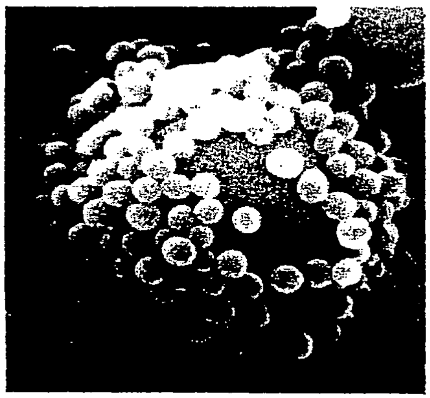


FIG. 7(2)

FIG. 7(3)

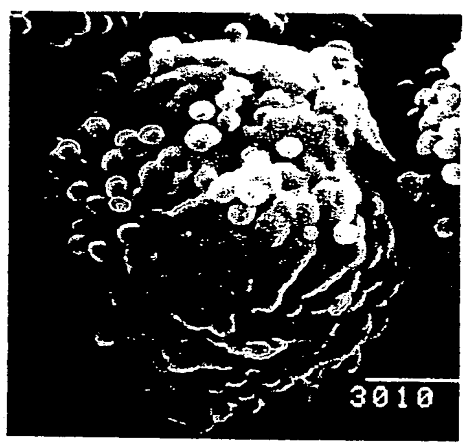


FIG. 7(4)

FIG.8(1)

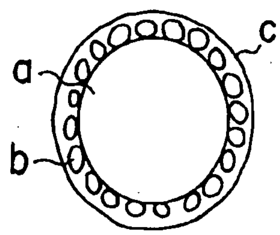


FIG.8(2)

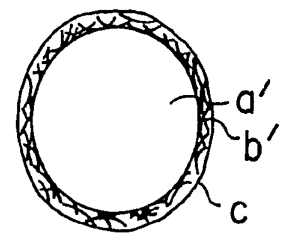


FIG.8(3)

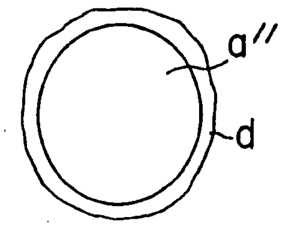


FIG.8(4)

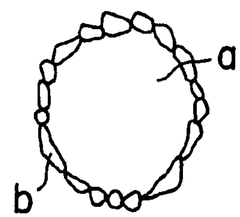


FIG.8(5)

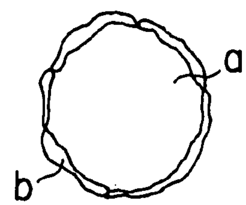


FIG.8(6)

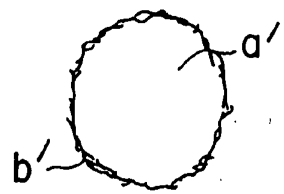


FIG.8(7)

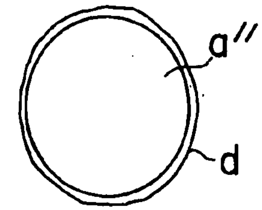


FIG.8(8)

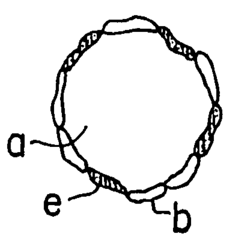


FIG.8(9)

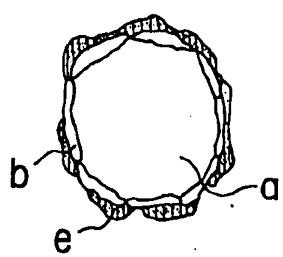


FIG.8(10)

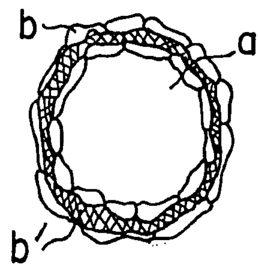


FIG.8(11)

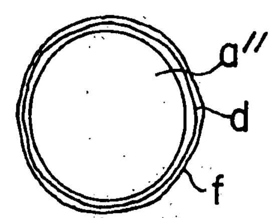
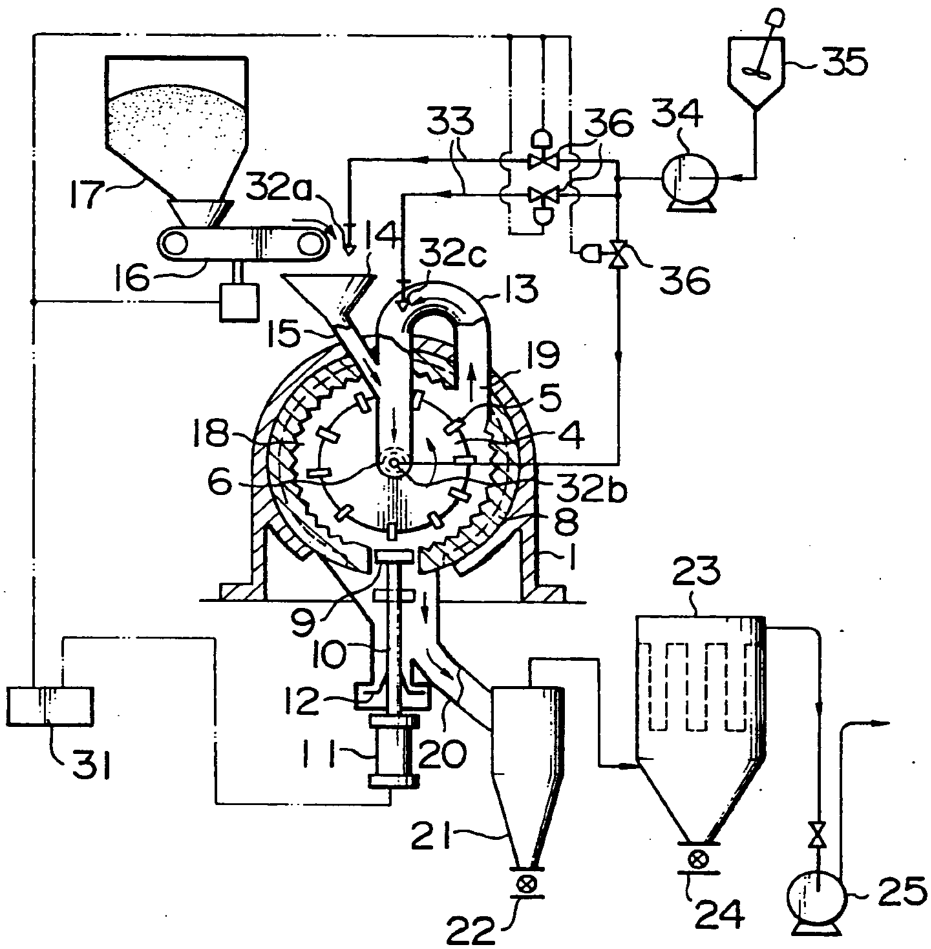


FIG. 9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32a
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32c
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16
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32b
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FIG.10

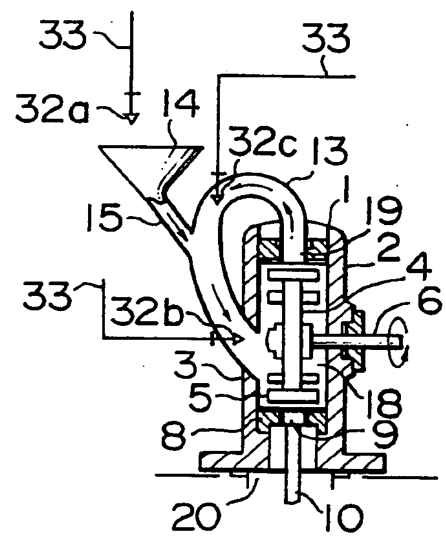
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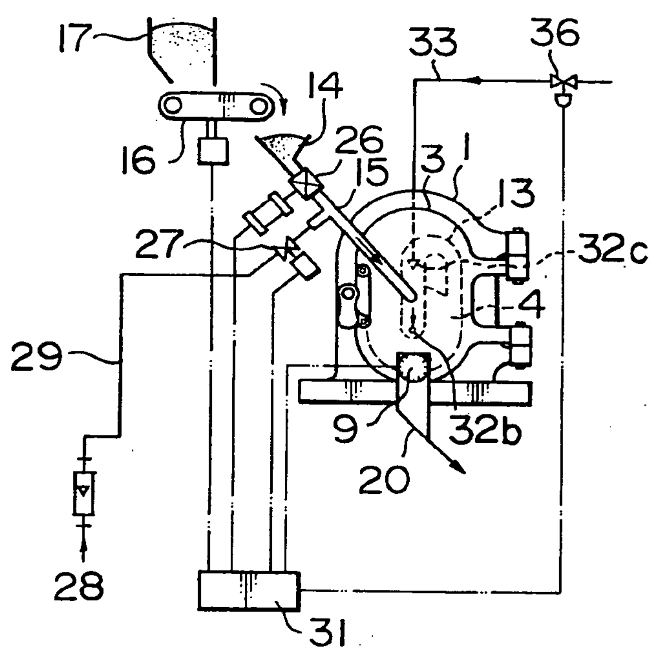
FIG.11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32b
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FIG.12(1)

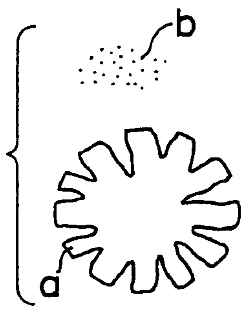


FIG.12(2)

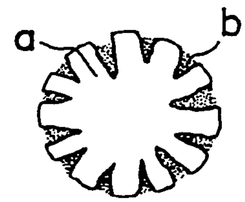


FIG.12(3)

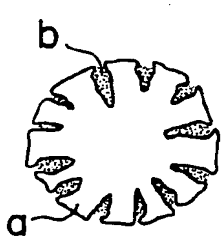
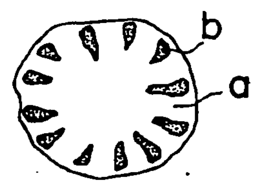
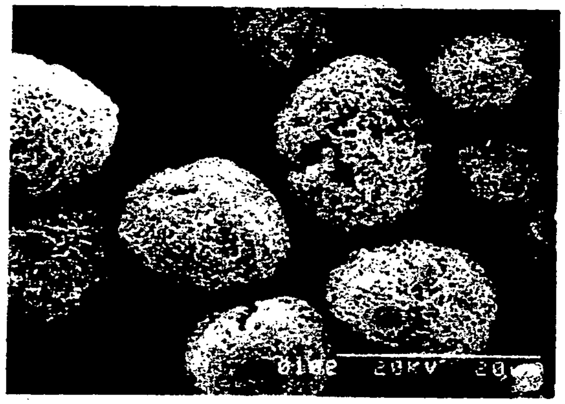


FIG.12(4)



F I G. 13(1)



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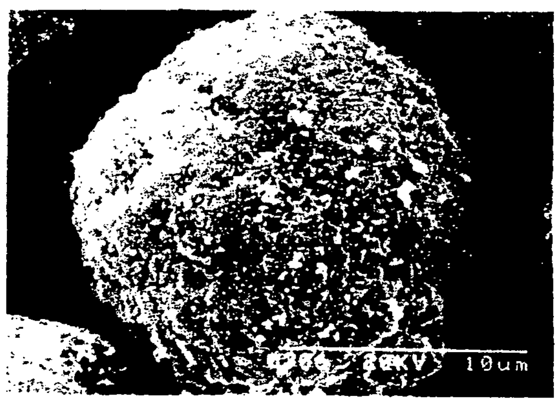

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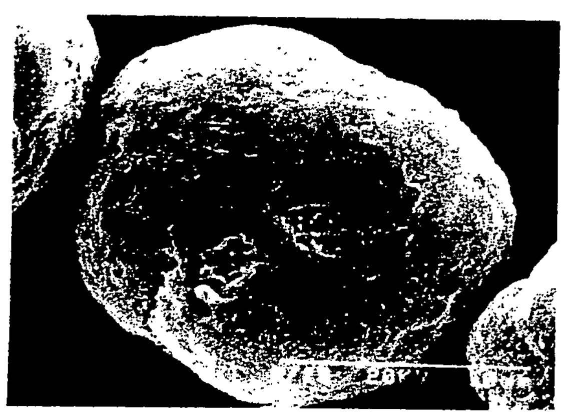

F I G. 14(1)

F I G. 14(2)